DEEP UNDERGROUND REACTOR (PASSIVE HEAT REMOVAL OF BWR WITH HARD NEUTRON ENERGY SPECTRUM)

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Light water reactor with hard neutron spectrum

- NERI program
- Tight lattice and high concentration of fissile material (Pu)
- Thorium fertile material : Non proliferation
- Negative void coefficient without void channel
- Heat removal problem for accident case of LOCA etc.

Under ground nuclear power plant

- Sacharov
- E. Teller
- Pu and Elec. gene facility in Enisei River
- Graphite reactor
- Entombment

Deep under ground

- Deep storage facility of HLW
- Yucca Mt project few tens miles of tunnel
- High energy physics facility: Homestake,
- Grand Sasso
- Super-Kamiokande, LHC
- Neutrino experiment(graded)
- Radioactive contamination of ground water by muons

Passive heat removal system

- Accident scenario
- Loss of coolant
- Loss of on site- electricity

Emergency cooling

- (borated water in PWR) water stored in the containment building double concrete
- Expensive and problem of seismic (earth quake)
- To store of water not so large quantity trip time will be 30 –1 Hour

Passive safety

- Natural circulation of water coolant
- Tight lattice fuel assembly requires several times pumping power than regular BWR
- Pressure difference of BWR 2-3 atm
- For tight lattice 8-10 atm (80 -100 meters of water channel height)
- Enough room for deep under ground reactor
- Decay heat can be removed by natural circulation

Pressure vessel of LWR

- PWR : 150 atm
- BWR: 100 atm
- deep under ground provide this high pressure PWR: 1500/ 2.5= 600meters
  BWR:1000/2,5 =400 meters
- Thin pressure vessel

Heat removal from HCLWR

- Pressure vessel of conventional LWR
  PWR: 150 atm, BWR: 100 atm
- pressure drop in heat removal channel
- PWR : 2 atm BWR; 2.5 atm
- Tight lattice LWR
- about 4 times of the conventional
- PWR: 8 atm BWR : 10 atm

Downcomer height

- PWR : 80 meters BWR: 100 meters
- Turbine is located in close to reactor
- Vacuum condenser can be located 80 -100 meters high above turbine.
- Low pressure steam climb up will be cooled by vacuum condenser.
- Liquid water can provide the circulation pressure.

Shielding of radiation

- Earth shielding instead of reactor container building
- Reduces Seismic problem
- Avoid Chernoville and TMI type hazards
- No evacuation problem like Shoreham (LILCO)
- Near Consumer site (Tokyo-bay, New York-Manhattans).
- provide also good protection of RAW leak

Close to consumer

- Not ask the people in remote area
- Short transmission line ; this is expensive as NP facility
- Fuel processing facility (can be dry process) in deep under ground)
- No fuel transport
- MIT reactor in Cambridge

Public Acceptance

- Safety
- not my backyard
- Tritium leak
- Tokai-mura Critical accident
- Chernoville, TMI accidents

Technology of under ground facility

- Economical Digging
- Tunnel building Yucca Mt etc.
- Geothermal power plant 500-1000 deep near magma.
- Not expensive
- Cost of underground facility is not so expensive as people imagine
- Homestake gold mine has more than 400 miles long tunnel in underground of 4000-8000 ft deep

High pressure due to the earth gravity force

- BWR 100 atm
- PWR 150 atm
- super critical steam cooled reactor 250 atm
- use of earth gravity force
- He cooled reactor: Thin pre-stressed concrete pressure vessel
- Na , PBS , Pb-Bi cooled : low pressure, however, high pressure steam generated ; thin containment building

Underground Facility

- Kamikande neutrino experiment
- Shielding of accelerator Proton accelerator)
- Cost of digging the under earth is less than 1 million dollar for 10 meter dia 1000 meter depth hole?
- E Teller proposed the graphite reactor He cooled
- After reactor life time it will be embedded to

Economical consideration

- Comparison to the deep under ground for high level waste storage(500-1000 meter deep)

- Radiation hazard Chernoville type reactor is in the mountain
- No Long Island evacuation (Shoreham LWR)

Economics

- Short transmission line
- No thick containment building
- no evacuation
- Modular type small facility
- Nuclear Island concept
- Use of Mountain with water supply for condensing steam

Near Consumer

- No transportation of fuel
- Processing using the dry processing can be built in under ground.
- On site fuel processing
- Contamination of sea water has to be prevented,

Site near city

- Near city (Tokyo Bay)
- Short transmission
- Transmission of electricity is comparable with electricity generation
- Avoid the high cost of high voltage transmission line (hazard to buy land)
- Near city is save the cost for transmission cost

Near consumer

- 10% electricity loss is very expensive.
- Under ground cable (Transmission from France to Sweden)

Natural Gas Power Plant

- Comparison with Natural gas plant
- Natural gas combined turbine in Tokyo Bay
- Fire hazard transport of gas to
- Congestion of marine (sea) traffic
- Storage of natural gas

Geo-thermal Energy

- Sea side of Tokyo bay or Mountain are near lake (Hakone area) Geothermal
- Use of reactor heat for stable supply of hot spring. (Radium Hot spring)
- Heat pipe for air condition (Hot and cool)

Accelerator Driven Reactor (ADS)

- Beam injection can be done
- beam expansion tube
- Deep sea or hole provide a high pressure of 100 atm

Deep under ground ADS

- Regular vertical configuration
- Vertical injection of proton beam
- Expansion of proton beam
- Protect beam window from radiation damage
- 1Gev small production of muons

Other than electricity generation

- Transmutation of MA or LLFP using hard neutron energy spectrum
- Super-critical steam cooled reactor
- Use of Low grade heat (not high temperature) use of Geo-thermal
- In the future Tsinghua University heat
- Concrete technology (Sugama at BNL)

CO2 problem

- Putting to CO2 into deep sea (liquid CO2 High pressure)
- Aqua firming (Fishing) production
- Geological survey has to be done (Sinking of the Osaka Inter. Air Port 30 Cm / year, 1 Billion $)

Transmission Line

- Under ground cable (Transmission from France to Sweden)
- Not in my backyard (remote place, but not disturbed by city people)
- Sharing burden (not asking the remote area)
- Super-conducting transmission is not cheap
- There is no so many land
- Even France has not

Deep under ground

- **Comparison to the deep under ground for high level waste storage(500-1000 meter deep)**
- **Geothermal (more than 1000 meter**
- **Deep mountain Russia reactor in side mountain Near North Mongolia**
- **Radiation hazard Chernoville type reactor is in the mountain**
- **No Long Island evacuation (Shoreham LWR)**
- **Avoid from smart bombing**

Deep under ground facility

- Enough space for many facility
- Emergency borate water to remove the heat
- to provide large pressure drop
- long accelerator (LINAC) for high power
- magent for beam controlling
- PWR also possible
- thin pressure vessel replacement of PV.
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High Burn-up LWR

- Tight lattice High Pu concentration
- Thorium fertile material
- Hard neutron energy spectrum
- High burn up
- Negative void coefficient (Th)
- Heat removal (Loss of coolant in Emergency)

Passive System for heat removal

- Island can be protected
- Deep sea is also candidate.
- LWR is well proven technology
- not for Pb Pb-Bi technology
- Na is reactant fire hazard.